Flight Software

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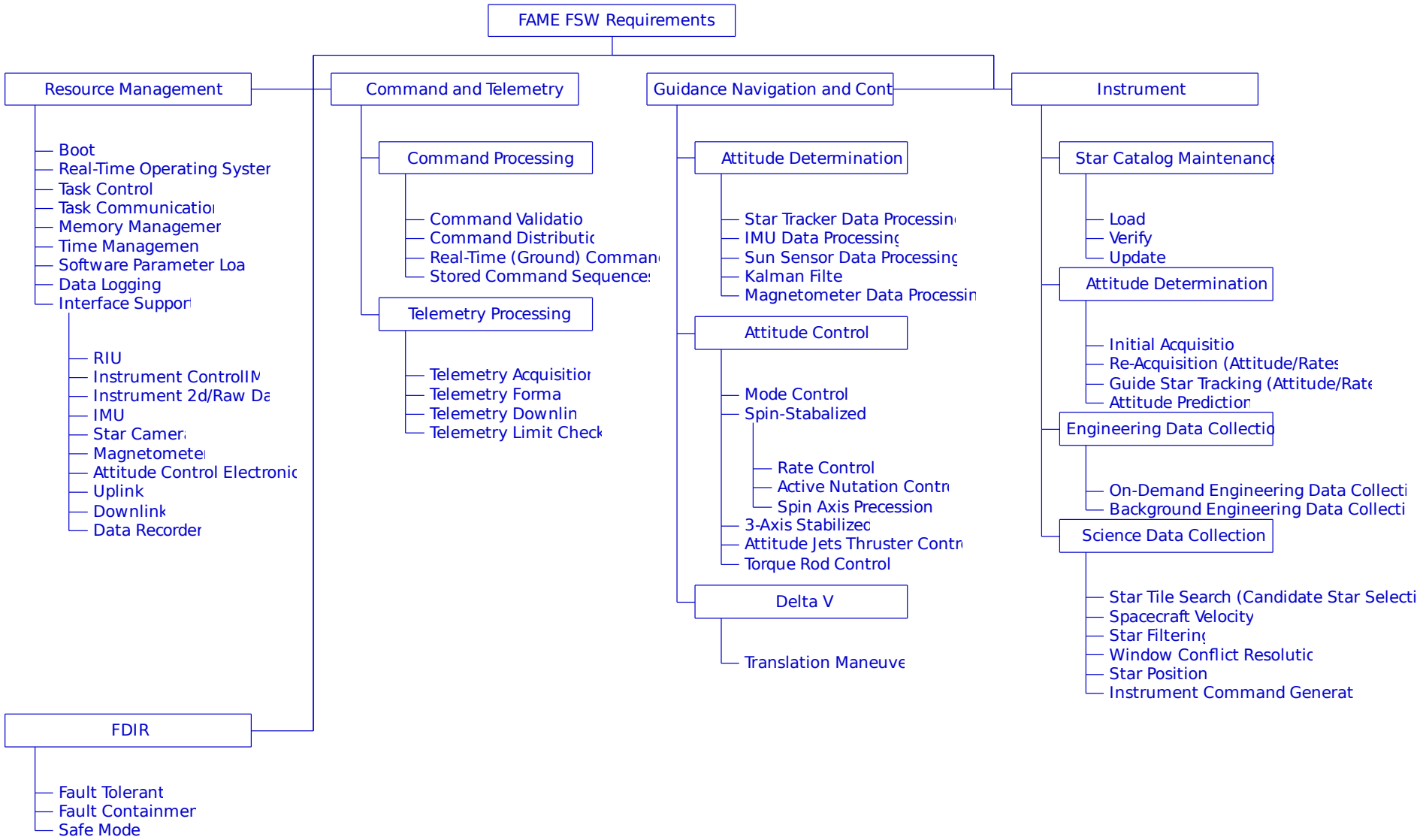
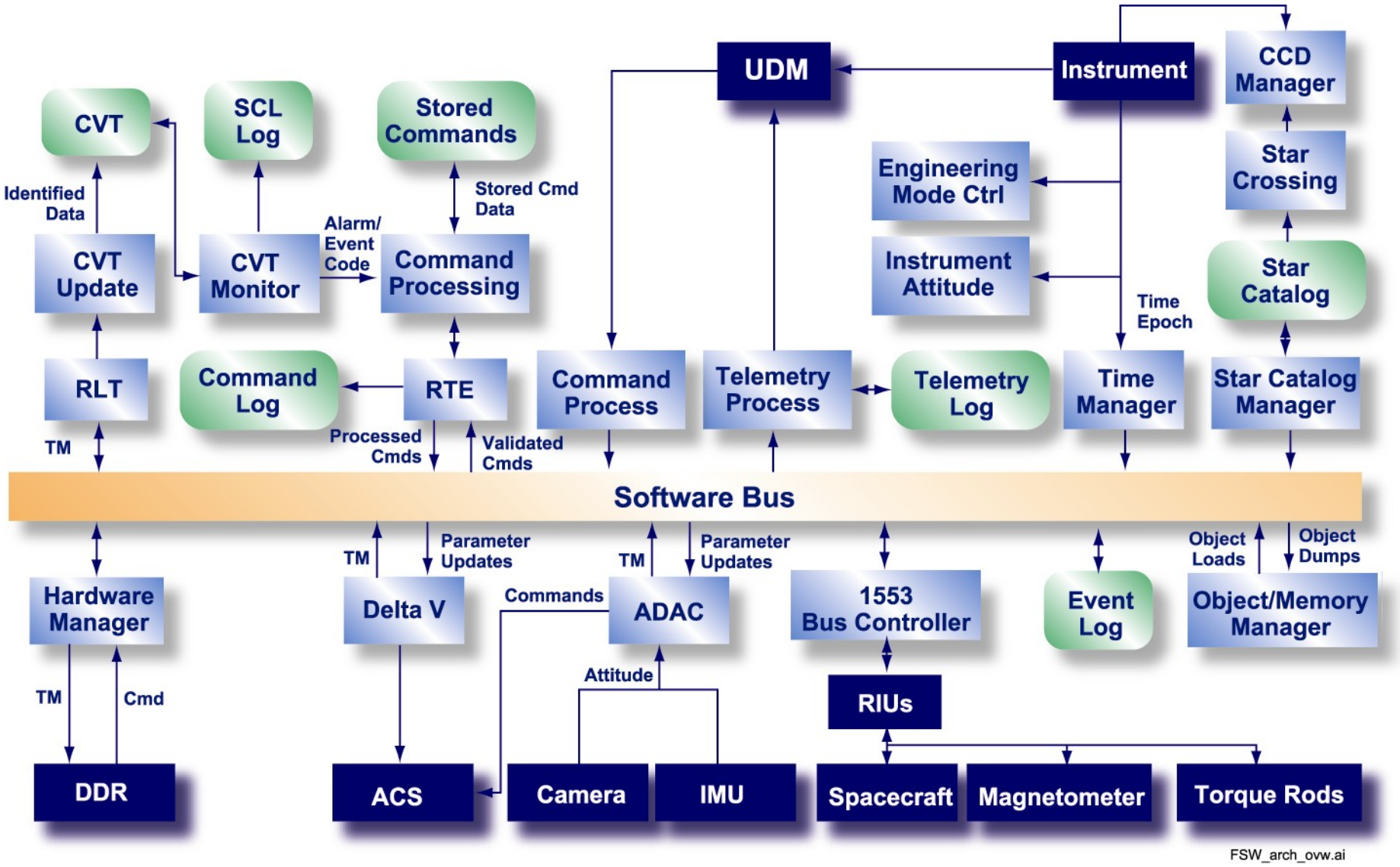
Flight Software Top Level Requirements



FSW Architecture Overview



SLOC Estimate - Summary

Function	SLOC	Reuse	Percent Reuse
Star Crossing	2000	0	0%
CCD Manager	1500	0	0%
Star Catalog Manager	500	0	0%
Engineering Modes	2000	0	0%
Instrument Attitude	4000	0	0%
Attitude Determination and Control (ADAC)	6600	2500	38%
Delta-V	900	500	56%
Math Library	600	440	73%
Star Tracker Control	600	0	0%
Downlink Processing	3800	0	0%
Return Link Table	820	800	98%
Uplink Processing	3400	3000	88%
Memory Manager	1200	1100	92%
Memory Library	2400	2200	92%
Stored Command Processing	4200	4000	95%
Telemetry Processing	680	660	97%
Resource Management	25500	16700	65%
Device Drivers	5500	417	8%
OS Support (BSP)	1200	1200	100%
Boot Monitor And Diagnostics	6800	4700	69%
Total	**74200**	**38217**	**52%**

COTS	SLOC	COTS Use	Percent Use
Spacecraft Command Language (SCL)	6200	6200	100%
RTOS (VxWorks)	28800	28800	100%
Total	**35000**	**35000**	**100%**

Grand Total	**109200**	**73217**	**67%**

ICM FSW Code Re-Use - Overview

(Interim Control Module - utilized a RHC-3001 based spacecraft controller)

As is or Slight Tailoring

Some Tailoring

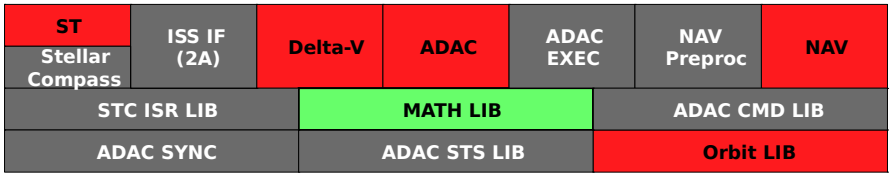
Function Needed, Reuse Unlikely

Function fo FAME not Needed

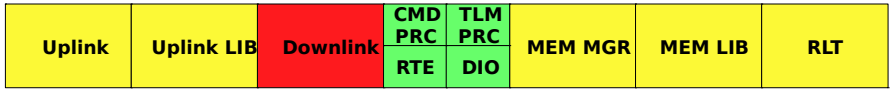
Major CT & RM definition and design issues that are a delta between FAME & ICM
- HW Interfaces (Device drivers)
- Local Bus (HWIF & Protocol Layers)
- Diagnostic Support

ADAC- Some library and conceptual reuse, but overall requirements and design needs to be specificied and developed

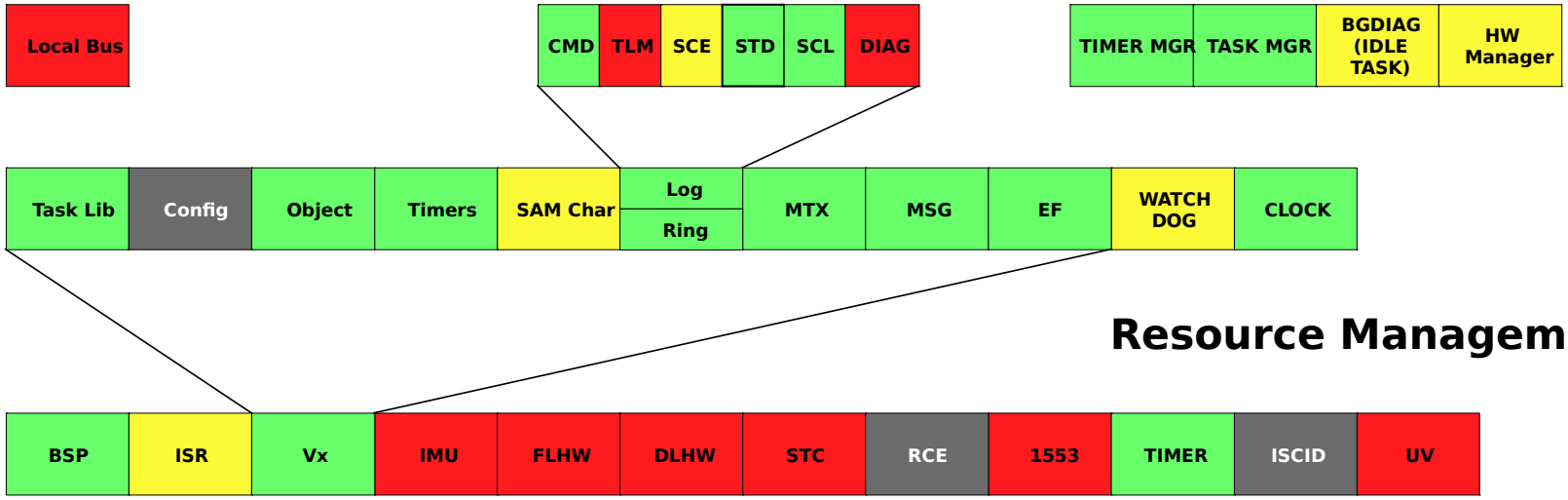
Boot definition and design issues that are a delta between FAME & ICM
- Extended Diagnostics
- Telemetry Processing



Attitude Determination and Control (ADAC)



Command & Telemetry



Resource Management

FSW Milestones

- **Design Reviews**
  - **10/2001: Preliminary Design Review**
  - **2/2002: Flight SW Design Review - Instrument Functions**
  - **5/2002: Flight SW Design Review - Bus - Attitude Determination and Control**
  - **8/2002: Critical Design Review**
  - **9/2002: Detailed Design Review - FSW Subsystem Review/Remaining Detailed Design Issues Resolved**
- **CT&DH Development Milestones**
  - **3/2002: FSC Breadboard**
  - **10/2002: CT&DH Flight Delivery and Start of CT&DH / Bus Electrical Deck Integration**
- **Potential Integration Opportunities at LM ATC**
  - **NRL Will Be Working With LM ATC to Secure at Least Two Early Opportunities to Perform Integration Testing Between the Bus CT&DH and the Instrument Electronics**
  - **4/2002: Breadboard FSC / Engineering Model Instrument DPA Integration Test**
  - **11/2002: Breadboard CT&DH / Instrument DPA Subassembly Integration Test**
  - **7/2003: Breadboard CT&DH / Flight Instrument Integration Test**
- **Bus/Instrument Integration at NRL**
  - **12/2003 - 8/2004 Observatory Integration and Test Activities**
- **FSW Acceptance**
  - **9/2003: Flight SW Test Readiness Review**
  - **10/2003 - 12/2003: Flight SW Formal Qualification Test (FQT)**

Flight Software Builds

Build 0 - 12/2001

- Support FSC Target Processor
- Represent ICM Heritage Port
- System Resource Manager
  - Resource Manager APIs
  - Task Manager
  - Object & Memory Loads
- Command and Telemetry
  - Network Command & Telemetry
  - Stored Command Processing

Build 1 - 4/2002

- Support FSC Breadboard
- Support Instrument Interface Testing
- Boot Monitor
  - Full Functionality
- System Resource Manager - Complete
  - Breadboard H/W (FSC) Interfaces
- Command and Telemetry
  - H/W Command and Telemetry
- Instrument
  - Instrument Commanding - Ground Issued
  - Image Acquisition

Build 2 - 10/2002

- Support Electronics Deck Integration
- Boot Monitor
  - Tested and Intended Final Release
- System Resource Manager - Complete
- Command and Telemetry - Complete
  - 1553 Bus Controller
  - Hardware Command and Telemetry
- Guidance Navigation and Control
  - Attitude Determination
- Instrument
  - Catalog Management
  - CCD Control
  - Initial Diagnostic Support (Engineering Mode)

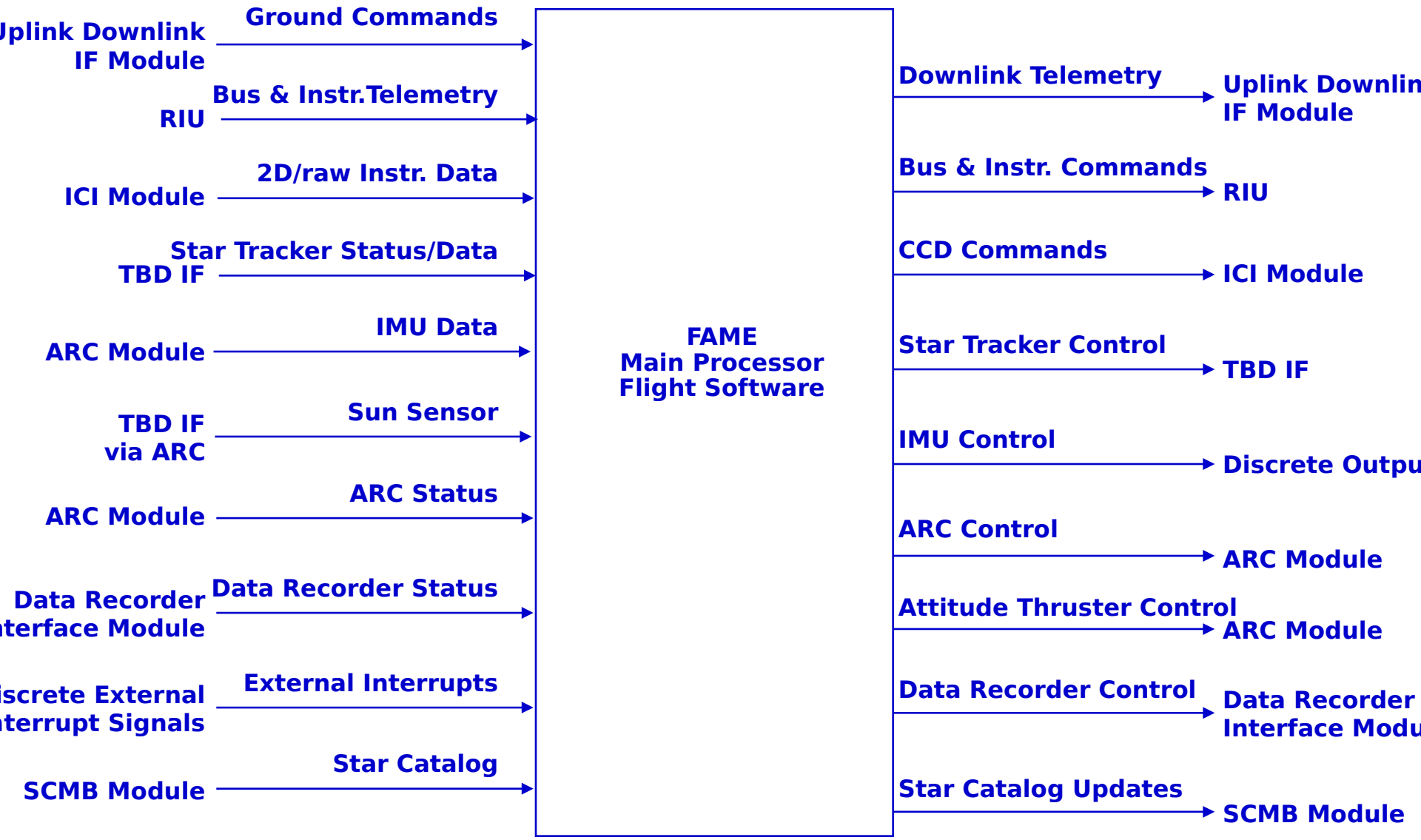
Build 3 - 6/2003

- Full Functionality
- Boot Monitor - Complete
- System Resource Manager - Complete
- Command and Telemetry - Complete
- GNC - Complete
  - Attitude Control
- Instrument - Complete
  - Attitude/Rate Determination
  - Attitude Predication
  - Full Diagnostic Support (Engineering Mode)

Flight Software Status
as of 10/30/2001

- **Development Environment**
  - **FSW Development Server, Raid, Backup, Workstations - SUN/Solaris Based, Operational**
  - **Source Code Configuration Management - Clearcase, Operational and Populated**
  - **Software Only Test Bed - WindRiver VxSIM 5.4, Operational**
  - **Target OS - WindRiver VxWorks 5.3.1 in Use, 5.4 Pending Upgrade to Support RHC-3001**
- **Target - Functional Equivalent Unit (FEU) Chassis**
  - **Commercial VME Chassis**
  - **Harris RHC-3001 Processor Module**
  - **PMON and Network Boot Loader in EEPROM**
  - **128 Mbytes DRAM**
  - **Ethernet Connectivity**
  - **Asynchronous Serial Diagnostics Port**
- **Flight SW - Build 0**
  - **ICM Resource Management - Ported and Operational**
  - **Command Handling - Ported and Operational**
  - **Telemetry Formatting - Design Complete, Implemented and Under Test**
  - **Stored Command Processing - Ported and Operational**
  - **FSC Test Functions - Development in Progress and Supporting FSC Component Test Efforts**
  - **Instrument Function Prototyping - Preliminary Results Available**

FSW External Interfaces



Fault Detection, Isolation and Recovery Requirements

- **Fault Detection**
  - **Specified Fault Identification Logic**
    - **Fault Identification Details to Be Determined**
    - **Areas of Concern Include (But Not Limited to) Attitude Sensor Reasonability Checks, Attitude Determination Solutions, Attitude Control (Intended vs Maintained)**
- **Fault Containment**
  - **Sanity Checks on FSW Inputs (Commands, Parameters, Sensor Inputs)**
  - **Protection for Consumables (Thruster Usage/Fuel)**
  - **Protection Against SW/HW Upsets - Processor/Task Watchdog**
- **Fault-Tolerant - Reaction to Failures Is Dependent on the Mission Phase and Dependent on the Nature of the Failure**
  - **Actions That Will Be Considered:**
    - **Use Redundant Hardware (Autonomous Recovery) - When Required Time to Effect a Recovery Is Short**
    - **Safe-Hold (Autonomous Mode Transition) - When Required Time to Effect a Recovery Is Short**
    - **Stop Action (Inform Ground and Wait for Instructions) - Time to Effect Is Long**
    - **Reset Processor to Idle (Watchdog Timeout) - Return to Boot/Initial Processor State**
    - **Reset Processor to Operational (Watchdog Timeout) - Recover to Intended Operational State**

Attitude Determination - Bus Sensors

- Two Attitude Determination Modes: 3-Axis and GTO Spin Stabilized
- Sensors: Star Tracker (Quaternion Generation), IMU, Sun Angle Sensor
- 3-Axis Mode
  - Kalman Filter
  - Inputs: IMU and Star Tracker
- GTO Spin Stabilized
  - Kalman Filter
  - Inputs: IMU and Sun Sensor
- Outputs for Both Modes
  - Time Tagged Attitude Quaternion, Body Rates and Estimated IMU Biases
  - Status, Including Mode and Validity Flags
- Initialize to Rate Only Data, Transition to 3-Axis Mode After 3 Successful Star Tracker Inputs
- During Instrument Operation May Power Up Only 1 IMU At a Time (i.e. Cold Spare)
- Provide for Operating Both IMU's During Critical Phases, e.g. Preparation for AKM Burn

Attitude Control

- Seven Control Modes
- Standby Mode
  - Monitor Attitude During Instrument Operation
  - No Thruster Firing
- Inertial Pointing Mode
  - Point to Any Inertial Attitude
  - Pointing Tolerance Defined in Command
  - Sub Modes With Control Parameter Variations to Cover Various Spacecraft Configurations and Delta-V Maneuvers
- Safe Hold Mode
  - Before Solar Array Deployment: Spacecraft Z Axis Perpendicular to Sun; Slow Rotation About Z
  - After Deployment; Spacecraft -Z Axis Pointed at Sun; Slow Rotation About Z
- Rate Control
  - Controls Body Rates in Each Axis
- Open Loop Burn Mode
  - Fire Specified Thrusters for Specified Intervals
  - Can Be Used for Coarse Maneuvers
- Active Nutation Control Mode
  - Damps Nutation During GTO Spin Stabilized
- Spin Axis Precession Mode
  - Precesses Spin Axis During GTO Spin Stabilized

- Commanded Mode Transitions Restricted by:
  - Current Mode
  - Spacecraft Configuration
  - Attitude Determination Status
- Autonomous Mode Transitions
  - Maneuver Completion (I.e. Open Loop Firing)
  - System Failures
  - Instrument Protection From Solar Exposure
- Attitude Control Task Cycle Rate May Be Mode Dependent
- All Closed-Loop Modes Use Thruster Firing Tables to Convert On/Off Decisions Per Axis to Specific Thrusters

Command and Telemetry Processing

Command Processing

- CCSDS Command Format and Protocol Compliant
- Commands Shall Be Authenticated
- Command Type, Parameter and Context Validation
- Command Distribution
  - SW Commands
  - Spacecraft Subsystem (I.e. HW Commands)
  - Instrument Control
- Parametric Load Support
- Memory Load Support
- Stored Command Sequence Support
  - Sequences Are Initiated by Request or at a Specified Time

Telemetry Processing

- State of Health Telemetry Collection
  - SW Telemetry
  - Spacecraft Bus Telemetry (HW Telemetry)
  - Instrument State of Health
- Diagnostic Telemetry Collection
  - SW Diagnostics
  - High Rate HW Telemetry Collection
  - Instrument Diagnostics
- Memory and Parametric Table Downloads
- Spacecraft Event Reporting
- Summary Status Flags
- Telemetry Logging
- Telemetry Downlink Is CCSDS Compliant
- State of Health Telemetry Rates are 1K and 8k Bits/Second
- Diagnostic dOwnlink Rates in Excess of 8K Bits/second Will Be Supported

FSW Boot and Resource Management

- Software Support
  - Software/Parameter Table Handling
  - Data Logging Services
  - Time Management
  - Inter-task Communications
  - Task Management
- Hardware Support
  - Interrupt Handlers
  - Device I/O
  - Background Diagnostics (Non-Invasive)
- Time Management
  - Support Space/Ground Time Synchronization Functions
    - Telemetry Time Tagging
    - Commanded Time Set and Adjust
    - Instrument Counter/Ground Synchronization
  - Support On-Board Time Distribution
  - Support On-Board Time Maintenance
- Boot
  - Power-Up Diagnostics
  - Extended Diagnostics
  - Software Re-Load
  - Alternate Boot - crit Command Controlled
  - Memory Dump
  - Command Handling (CCSDS Compliant)
  - Telemetry Formatting (CCSDS Compliant)
  - Autostart to Mission Code - crit Command Controlled

Instrument Control Key Performance Requirements

- Star Catalog
  - 40,000,000 Stars
  - Accept Catalog Updates at Uplink Rate (~10 Updates/sec)
- Star Processing Performance
  - Process a Maximum of 2000 Observations Candidates Stars Per Second Entering Both Fields of View (FOV)
- Window Creation
  - Predict the Time and Position of a Stellar Image on Each CCD Half in the Focal Plane to +/- 0.87 Micro-Radians
- Attitude and Rate Determination
  - In Support of Trim and Acquisition Activities
    - Attitude to +/- 250 Micro-Radians
    - Rotation to +/- 5 Micro-Radians/Second
  - In Support of Observation Collection (at Completion of Acquisition)
    - Attitude to +/- 0.3 Micro-Radians
    - Rotation to +/- 0.3 Micro-Radians/Second
- TDI Management
  - Shall Maintain TDI Clock Period to +/- 20 Nano-Seconds of the Star Transit Time of a Single Line of CCD

Attitude Determination - Instrument Data

- Attitude Determination Using Instrument Data Will Be Utilized for:
- Initial Acquisition
  - Assumes Observatory Rotation Rates Have Been Stabilized by the Bus and Are Close to Mission Requirements
  - Utilize Bus to Determine the Attitude and Rates to Set TDI Rate and Place Acquisition Windows
  - Utilize Acquisition Stars Identified in the Star Catalog
  - Instrument Will Be Used to Collect Large 2D Windows (600 X 600 Window Size)
  - Support Search Pattern to Capture Acquisition Star (Ground Processing Will Process the Images)
  - Initial Acquisition Will Remove Unknown Alignment Errors Between Star Tracker and Instrument FOV Boresights
- Nominal Acquisition (Reacquisition)
  - Alignment Errors Between Star Tracker and Instrument FOV Boresights Have Been Removed
  - Utilize Bus to Determine the Attitude and Rates to Set TDI Rate and Place Acquisition Windows
  - Utilize Acquisition Stars Identified in the Star Catalog
  - Instrument Will Be Used to Collect Large 2d Windows (600 X 600 Window Size)
  - No Search Pattern Required
  - Onboard Processing Will Use 2D Images to Determine Attitude and Rates
  - Once Acquired, Transition to Science Data Collection and Attitude/Rate Tracking
- Attitude/Rate Tracking
  - Performed While in Science Data Collection Mode Using Small 2d Windows to Capture Guide Stars
  - Determine Updated Attitude and Rate Information - Updated Rate Information Will Be Used to Control TDI_RATE
- Attitude Prediction
  - Use Attitude/Rate History and Model to Predict Spacecraft Attitude
  - Adequate Attitude Knowledge to at Least 6 Seconds Into Future Is Needed for Proper Window Placement

Window Data Collection

- **Use Predicated Attitude and Rate Knowledge to:**
  - **Select Candidate Tiles**
  - **Search for Candidate Observations (Acquisition, Guide, Science and/or Engineering)**
  - **Perform Rate Limitation Filtering Only When Needed**
  - **Perform Star Motion Related Corrections, If Needed**
    - **Parallax, Proper Motion**
  - **Perform Spacecraft Velocity Correction (Stellar Aberration)**
  - **Resolve Window to Window Conflicts**
  - **Schedule Observation; Column, Time**
- **Use Virtual Frame (4096 Row Period) Timing and Set of Scheduled Observations to:**
  - **Select and Group the Candidate Observations Per CCD Half**
  - **Perform Optical Distortion Correction**
  - **Resolve CCD Half Boundary and Virtual Frame Boundary Conflicts**
  - **Convert Observations to Instrument Charge Injection Commands (Virtual Frame N)**
  - **Convert Observations to Instrument Window Commands (Virtual Frame N+1)**
- **Output Instrument Instruction Sequences for Each Virtual Frame for Each of the Three Instrument Control Interfaces**

Observation (Star) Catalog Maintenance

- **Intended Observations Grouped by Tiles**
  - **Tiles Represent Regular Segmentation of the Celestial Sphere (Prototype Efforts Use ~40,000 Tiles)**
  - **Algorithm Review/Refinement May Decrease the Size of the Tiles and Thus Increase the Number of Tiles**
  - **Current Storage Requirement Per Tile Is 24 Bytes**
- **Catalog Will Support at Least 40,000,000 Static Observation Entries and 40,000 Dynamic Observation Entries**
- **Static Observation Attributes (12 Bytes)**
  - **Star_ID:16 bits; /* Star Identifier in Tile */**
  - **Mag: 8 bits;/* Magnitude*16 (Magnitude Range 0.0-15.0) */**
  - **Size: 1; /* Window Size (Small, Large) */**
  - **Bin_Type: 1; /* BinningType (1d, 2d) */**
  - **Gain: 1; /* Gain (lo, hi) */**
  - **acqStar: 1; /* Acquisition Star Flag (True, False) */**
  - **gridStar: 1; /* Guide Star Flag (True, False) */**
  - **colSeq: 3; /* Collection Sequence (0-7) */**
  - **ra; 32; /* Right Ascension - ieee Float*/**
  - **dec; 32; /* Declination - ieee Float*/**
- **Dynamic Observation Attributes**
  - **Identical Fields As the Static Observations With the Addition of:**
  - **Pointer to Next Dynamic Entry (32 Bits)**
  - **Proper Motion (TBD Format)**
  - **Parallax (TBD Format)**
- **Catalog Maintenance:**
  - **Static Observation Attributes Can Be Modified but Observations Cannot Be Added or Deleted**
  - **Static Observations Can Be Disabled Using a 7 for the Collection Sequence**
  - **Dynamic Entries Can Be Added, Modified and Deleted**
  - **Dynamic Entries Require Association With the Appropriate Tiles Based on Their ra/dec**
  - **The Catalog Load, Tile Re-Load, Catalog Re-Construction (If Necessary) Approach Is Still Under Consideration**
    - **Anticipate Some Limitations on These Activities During Science Observation Data Collection**
    - **Current Approach Will Support Catalog Load and Tile Re-Load During Science Data Collection**

Software Development Approach

- Software Lifecycle Model
  - Iterative / Incremental Development Model
    - Multiple Builds With Increased Capability With Each Build
    - Early Availability of Backbone Capability; Incremental Deliveries of Applications
- Design and Code Inspections / Review
  - Design and Code Walk Throughs
- Documentation (Tailored Mil-Std 498)
  - Essential Software Documentation
    - Integrated Software Development Plan
    - Software Requirements Spec (SRS)
    - Algorithm Description Documents (ADD) - ADAC, Instrument
    - Interface Control Document (ICD) - Space/Ground, Bus/Instrument, HW/SW
    - Software Design Document (SDD)
    - Software Test Plan / Description (STD)
    - Version Description Document (VDD)
- Configuration Management
  - Software Problem / Change Reporting System
    - Control Changes to Requirements, Interfaces, Incremental Builds, Formal Releases
- Quality Assurance
  - Peer Reviews and IV&V support

FSW Related – Documentation Status

Document Title	Document Number	System Requirements Review (Program)	Detailed Requirements Review (Bus FSW)	Preliminary Design Review (Program)	Flight SW Design Review - Instrument (FSW)	Flight SW Design Review - ADAC (FSW)	Critical Design Review (Program)	Flight SW Detailed Design Review (FSW)	Releases (FSW)	Test Readiness Review (FSW)	Formal Qualification Test (FSW)	System Test Readiness Review (Program)
Flight Software Development Plan	NCST-SDP-FM001	Draft	Draft	Preliminary	Release	Release	Update	Update		Final		
Flight Software Requirements Specification	NCST-SRS-FM001	Draft	Draft	Preliminary	Release	Release	Update	Update		Final		
Algorithm Description Document - ADAC	NCST-ADD-FM001				Draft	Release	Update	Update		Final		
Algorithm Description Document - Instrument	NCST-ADD-FM002				Release	Release	Update	Update		Final		
Space to Ground ICD	NCST-ICD-FM003		Draft	Draft	Draft	Draft	Draft	Release		Final		
FSC to FSW ICD	NCST-ICD-FM005		Draft	Draft	Release	Release	Final					
FSW Configuration Users Guide			Draft	Draft	Baseline	Baseline	Update	Update		Update	Update	
FSW Standard Operating Procedures			Draft	Draft	Final	Final	Final	Final				
FSW Test Description Document	NCST-STD-FM001				Draft	Draft	Draft	Draft		Final		
FSW Test Report	NCST-STR-FM001									Draft	Release	Final
FSW Version Description Document	NCST-VDD-FM001								Release			
IV&V Project Plan				Draft	Final	Final						

Software Testing Approach

- **Software Code and Unit Level Test**
  - **Performed on Developer's Platform**
  - **Verify Algorithm Development, Software Logic Debug**
- **Software Integration and Test**
  - **Performed on Common Desktop Computers (CDC) (Sun Workstation w/ VxSim)**
  - **Verify Functionality and Interfaces of Flight, Ground, and Simulation Software**
- **Software/Hardware Integration and Test**
  - **Early Integration and Test on SW Test Bed (STB) - Breadboard HW**
  - **Verify Software Executing on Target Processors With Realtime Operating System**
  - **Verify Software Interfaces With Breadboard/Brassboard I/O Hardware (e.g., C&T, ACS, RCS)**
- **System Integration and Test**
  - **Performed on Flight Spacecraft Hardware in EAGE Environment**
  - **Verify Flight Software With Spacecraft Hardware**
- **Operational Scenario Test**
  - **Performed on STB (breadboard HW) and EAGE (Flight HW)**
  - **Verify Operational Use of Software**
- **Independent Verification and Validation**
  - **Performed by Independent Contractor (via NASA/GSFC IV&V With SAIC as Subcontractor)**

Software Tools

- **Software Tools**
  - **Selected Processor** — **RHC3001**
  - **Target Operating System** — **Wind River System's VxWorks 5.4**
  - **Host Development Platform** — **Sun/Solaris**
  - **Language** — **C**
  - **Toolset** — **Wind River Systems Tornado II**
    - **Compiler** — **GNU Cross Compiler**
    - **Source Level Debugger** — **VxGDB**
    - **Diagnostic Tools** — **WindView and Stethoscope**
  - **Requirements Management** — **MS Access Database**
  - **Data Definition Management** — **Oracle Database With C based tools**
  - **Configuration Management** — **Rational ClearCase**
  - **Defect Tracking** — **Rational ClearQuest**

SQA, IV&V, Independent Review

- FSW Team Internal Reviews
  - Selected Peer Review of Detailed Design and Unit Code
  - Level of Effort Set at 3 Hours Per Week Per Team Member
- NASA/IV&V Effort Is in Its Initial Phase
  - IV&V Is Working With the FSW Team and Reviewing Documentation
  - Project Plan Being Worked
  - Long Term Memorandum of Agreement Is Being Worked
- Independent Reviews
  - NRL Internal Review Performed 5/2001 by Non-FAME Contractors With Spacecraft SW Domain Expertise
  - Covered Development Approach, SW Re-Use Strategies, Design Issues and Test Approach
- FAME FSW Design Reviews
  - FSW Team Is Planning Two Program Supported FSW Design Reviews (Prior to CDR) Focused on the FSW Instrument Processing and Attitude Determination and Control (ADAC)
  - The FSW Team Is Planning One Program Supported FSW Detailed Design Review (Just After CDR) Focused on Review and Closeout of Remaining Detailed Design Issues

Major Trade Studies

- **Full Redundancy Approach vs Distributed Processing With Degradation in Presence of a Failure**
  - **Current Approach Baseline: Full Redundancy**
  - **Approach Will Be Selected Based Processor Bandwidth Requirements**
    - **Determined by Analysis and Prototype Code Execution on the Target**
    - **Decision Will Be Made Prior to CDR**
- **Amount of Ground Processing vs Onboard Processing in the Area of Instrument Initial Acquisition, Spacecraft Trim, Re-Acquisition and Attitude Tracking**
  - **Current Approach Baseline:**
    - **Initial Acquisition: Ground Processing of Acquisition Star Search Windows**
    - **Spacecraft Trim: Ground Processing of Acquisition Star Windows**
    - **Re-Acquisition: Flight Processing of Acquisition Star Windows**
    - **Attitude Tracking: Flight Processing of Guide Star Windows**
  - **Approach Will Be Selected Based on Detailed Algorithm Specification**
    - **Complexity, Flexibility, Response Times and Processing Bandwidth Will Be Evaluated to Determine Whether These Functions Will Be Allocated to Flight or Ground Processing**
    - **Decision Prior Will Be Made to CDR**

Risks/Issues

- **Instrument Algorithm Definition**
  - **Mitigation: Instrument Algorithm Description Document (ADD) in Progress and Represents a Joint Effort Between NRL, USNO & LM ATC**
  - **The Instrument ADD and Associated FSW Detailed Design Will Be Presented in 2/2002 at a Flight Software Design Review**
  - **Instrument ADD to Be Released 3/2003**
- **Processor Throughput**
  - **Mitigation:**
    - **Algorithm Prototype Code Available and Being Adapted to the Target Processor for Throughput Analysis**
    - **Compiler Optimization Will Be Used**
    - **Algorithm Optimization Will Be Pursued**
    - **Implementation Optimization Will Be Pursued (If Necessary)**
  - **Algorithm Selection and Results From Prototype Code Will Be Available Prior to CDR**
- **FSW ADAC Detailed Requirements and Design Progress Awaiting Flow Down of Detailed ADAC Requirements Related to Sensor Selection, Thruster Positions, Control Mode Requirements**
  - **Mitigation: ADAC Algorithm Description Document to Be Worked, Represents a Lead Effort by NRL/ACS Team With NRL/FSW Team System Engineering Support.**
  - **The ADAC Add and Associated FSW Detailed Design Will Be Presented in 5/2002 at a Flight Software Design Review**
  - **ADAC ADD to Be Release 6/2002 (CDR)**

Processor Throughput Analysis - Preliminary Results

- Spacecraft Bus Functions Included in the Prototype Analysis Effort:
  - Bus Attitude Determination
  - Command and Telemetry Processing
  - Resource Management
- Instrument Observation Functions Included in the Prototype Analysis Effort:
  - Candidate Tile Selection
  - Candidate Star Selection
  - Star Projection Onto the FPA (CCDs)
  - Window Conflict Resolution
  - Window Command Generation
- Level of Prototype Representation
  - The Prototype Functions are Representative of the Required Functions and the Onboard Data Processing Pipeline, However, They Are Not Likely to Represent the Implementation of the Final Algorithm Selection
- Tests Environment:
  - FEU RHC3001 in Commercial VME Chassis
  - One-Quarter of Star Catalog (128mb)
- Level of Optimization for the Prototype
  - Algorithm Optimization - None Attempted
  - Implementation Optimization - Minimal
  - Compiler Optimization - Enabled
- Results:
  - Bus Functions (CTDH/RM) Take Up 7% of CPU, Measured Over 10 Seconds
  - The Total Pipeline Was Able to Process an Average 3300 Stars/Sec While Using 99% of the CPU
    - This Equates to 30% of the CPU for Each 1000 Stars/Sec
- Conclusion
  - Preliminary Results Indicate That After Algorithm and Implementation Optimizations, We Will Be Able to Generate Commands for 2000 Stars/Sec With a Single RHC3001 and Still Retain Acceptable Processing Margin

Processor Throughput Analysis - Preliminary Results

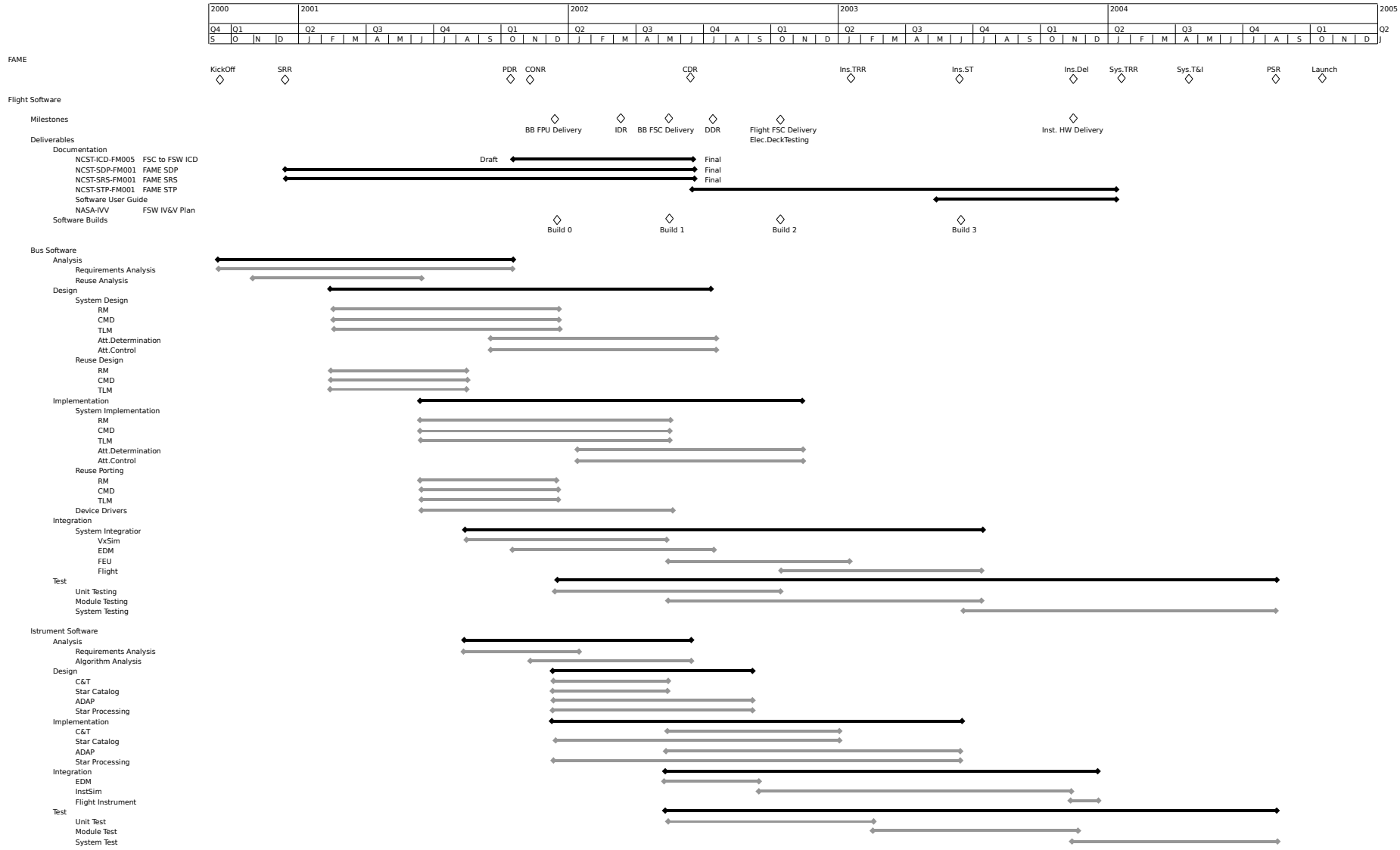
	%CPU @ average 2000 stars/sec
Bus Functionality Modelled (Measured Performance)	
Bus Attitude Determination	1
Command and Telemetry Processing	5
Resource Management	1
Instrument Pipeline Modelled	
Prototype Star Crossings	40
Candidate Tile Selection	
Candidate Star Selection	
Stellar Aberration	
Star Projection onto the FPA	
Prototype Star Commanding	20
Window Deconfliction	
CCD Command Generation	
Bus Functionality Not Modelled	
Bus Attitude Control	
Bus Hardware Telemetry (including RIU)	
Engineering Data Collection	
Instrument Processing Not Modelled	
Star Crossings	
Optical Distortion	
Proper Motion and Parallax	
Star Commanding	
CCD Command Generation (Complex)	
Star Catalog Maintenance	
TDI Rate Maintenance	
Instrument Attitude Determination	
Hardware Timing Support	
Total	67

Backup

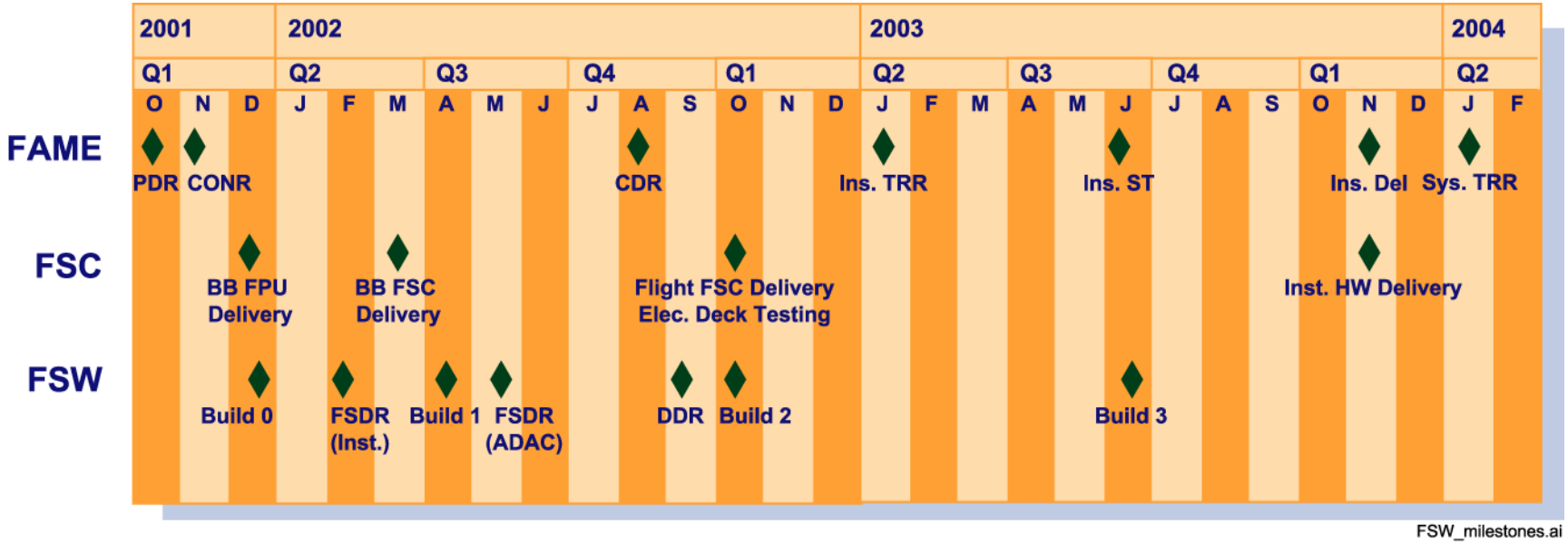
Throughput Analysis

- **Worst Case Processing**
  - **Spin Axis at Galactic Pole (RA=192.8583 deg, DEC=27.1333 deg)**
  - **Averaged 14852 Stars in FOV for Each 0.3 Deg Step in Rotation**
  - **Tile Density: 1169 Stars/Tile Average, 8941 Stars/Tile Max**
  - **Stars Commanded Per Step: 7401 Average, 25898 Max**
- **CPU Utilization**
  - **65% Was Used to Generate Star Crossings**
  - **35% Was Used to Generate Star Commands**
- **Geometries Used**
  - **1.25 Deg FOV**
  - **1.97 Deg “Large Radius” for Star Candidate Selection**
  - **10.5m Focal Length**
  - **61.44mm x 30.72mm CCDs**
- **Results Collected Over 18 Hours (~15000 0.3 Deg Steps)**

FSW Schedule



FSW Milestones



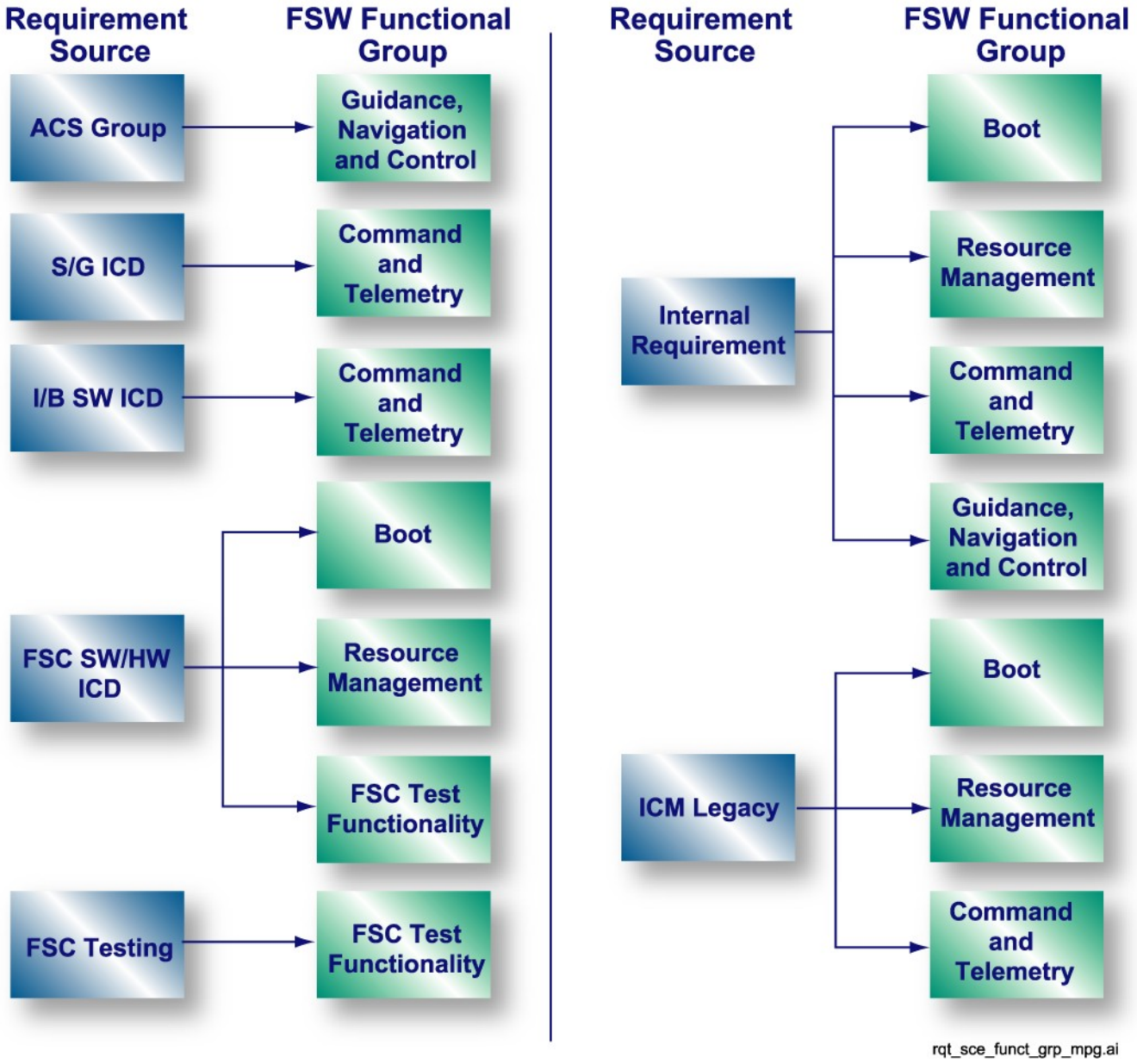
On-Board Logging

- All Logs Can Be Configured As Circular or Stop on Full
- Command Log
  - All Ground and Internal Command Requests and Dispositions
- Telemetry Log
  - State of Health Telemetry Storage
- Spacecraft Event Log
  - All Nominal and Off-Nominal Events Reported by FSW
- Diagnostic Log
  - Raw Sensor Data and Intermediate FSW Processing Results
- Stored Command Sequence Log
  - Text Messages Output From Command Script Execution
- Stdout Log
  - Capture Off-Nominal Activities From Operating System
- Trace Log
  - Trace Interrupt Receipt, Task Context Switch, Resource Locks

Stored Command Functions

- **Spacecraft Command Language (SCL) - COTS From Interface and Control Systems, Inc (ICS)**
- **SCL Ground Script Compiler and Database Support Integrated With Ground System (I.E. Command and Telemetry Databases)**
- **On-Board Processing Has Access to All State of Health Telemetry for Limit Checking and Decision Making**
- **On-Board Processing Supports High-Level Language Constructs and Has Access to Subset of All FSW Available Spacecraft Commands**
  - **Command Set Only Constrained by Operational Concept**
- **Scripts Are Triggered for Execution by Ground Command, Time (Absolute, Relative, Cyclic), Other Scripts or Rules**
- **Rules Are Triggered for Execution Based on User Defined Logic Using Telemetry Values and/or Spacecraft Events**

Requirement Source to Functional Group Mapping



FSW Development Flow